Development of a VR-enabled Serious Game to teach Astronomy and Computational Thinking to Middle School Students

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Abstract. *This text elaborates on the Master's work being developed by the primary author. Currently, Virtual Reality (VR) struggles to be implemented in Brazilian classrooms, and computational thinking and astronomy also struggle in spite of their academic importance. To combat this, a VR-enabled serious game will be developed for middle school students, tackling astronomical and computational thinking concepts. The game's impact on students will be assessed with questionnaires. With this, we expect to develop both a tool that can help teachers and students regarding astronomical and computational science education, and a research protocol to better understand the impact VR-enabled serious games can have on education.*

1. Introduction

Astronomy is an ancient study scaling back thousands of years, with strong connections to other fields, such as physics, geography, mathematics, technology, and others. The Brazilian National Common Curricular Base (Base Nacional Comum Curricular - BNCC) reinforces such relevance by including astronomy within the curriculum for students in K-12, albeit in a limited capacity [Bartelmebs et al. 2024] [Brasil 2018]. Despite this, in recent years, Brazilian education has struggled to support the efficient learning of astronomy, hence contributing to the reduction of interest of children in Science, Technology, Engineering and Mathematics (STEM) [Oliveira and Carvalho 2022].

Without the use of tools that can help students understand the scale and complex science behind concepts such as astronomical timescales or gravitational waves, essential for our understanding of the universe, teachers and students struggle to better teach and grasp the subject [Oliveira and Carvalho 2022] [Leão and Teixeira 2020]. Another option to teach astronomy are planetariums. In 2025, there were 129 planetariums in Brazil [Associação Brasileira de Planetários 2025], a small number, especially compared to the 39 million students in K-12 in 2023 [Brasil 2023a].

Similarly to astronomy, computational thinking [Wing 2006] is a field that has struggled to find space in Brazilian classrooms. Even though it is also included in the BNCC, many schools don't have the necessary technological infrastructure, with only 39.2% of schools having internet access and 44.7% with access to computers in 2023 [Anuário Brasileiro de Educação Básica 2024]. Public policies, such as Law 14,533 -

Política Nacional de Educação Digital (National Digital Education Policy) [Brasil 2023b], have been passed to help expand the education of computational thinking, but progress is slow.

The use of virtual reality (VR) can play a pivotal role to close the aforementioned gaps, as a tool that can provide immersive experiences for teaching and learning astronomy and computational thinking. Recent studies demonstrate the benefits derived from the use of VR in the education of both of these fields concerning the increasing student interest [de Andrade et al. 2023] [Chervonnyy and Güdekli 2024] [Agbo et al. 2023], despite limitations, such as lack of preparation by teachers and high costs. Therefore, we propose the use of VR as a complementary tool to teach astronomy and computational thinking for K-12 students of the Brazilian educational system.

To achieve this, we will conceive and develop a VR-enabled serious game about astronomy, incorporating computational thinking pillars, to challenge students with puzzles to progress during the levels, and investigate the students' learning and interest in STEM through questionnaires. The next section details the methodology.

2. Methodology

The applied research concerns the use of VR to improve the learning of STEM subjects for K-12 students in the Brazilian educational system. Exploratory research supports a deep understanding of the characteristics and limitations of existing VR-enabled educational tools in the field, through the study of relevant, recent scientific literature. As an MSc work in progress, the research roadmap will be in the following multi-stage design:

1. Designing and development of a VR-enabled serious game. The game will include 3 levels, each with approximately 30 minutes in length. The first level will take the player from the beginning of scientific and astronomical study, to astronomers and physicists such as Johannes Kepler, Galileo, Newton, and Einstein, up until human space exploration in the 20th and 21st centuries. The second level will place the player at a lunar colony, where they will perform scientific experiments and learn what it will take for the next step in space exploration. The third level will be a tour of the solar system, in which the player will visit other planets and moons, learning about how the solar system was formed, how it differs from other solar systems, and how Earth exists within this larger scope. The astronomical content will be aligned with, and at times surpassing, BNCC requirements. In order to progress, players will have to solve logic and computational thinking puzzles. The serious game will be developed in Unity 6 for Android devices. The devices used for VR implementation will depend of the project's financial resources, but will either be in Meta Quest 2 and 3 devices, or Android devices with do-it-yourself (DIY) HMD's. The Meta Quest devices, while more expensive, has a more immersive display and interaction system, however, the DIY HMD's are less expensive, and can developed by the students as part of their computational thinking classes.
2. Exploratory research. The aim is to identify and analyze existing Relevance of Science Education (ROSE) [Schreiner and Sjøberg 2004] and social impact assessment (SIA) questionnaires in the literature, and adapt and/or develop them to apply and evaluate the impact of the VR-enabled serious game and STEM education on students.

3. Pre-intervention assessment. Before the implementation of the educational intervention, the ROSE, SIA, and/or knowledge questionnaires will be applied to a sample of at least 30 K-12 students across two public schools located in the northeastern region of Brazil. These instruments will be used to establish baseline measures of students' interest in STEM subjects, key concepts in astronomy, and computational thinking. Teachers will also receive a questionnaire, to better understand difficulties faced with STEM education and the use of technology in the classroom. The project will be submitted to ethics committees at the chosen schools, and the participants will receive briefings explaining the project, where they will be able to better understand the proposed impacts of the project.
4. Group assignment. Participants (the K-12 students) will be randomly assigned to one of two experimental conditions: Group A (Experimental Group), in which the students will interact with the VR-enabled serious game; and Group B (Control Group), where the students will attend a traditional lecture covering the same content as the serious game, without the use of immersive technologies. The content will be equivalent in scope and duration across both groups to ensure content parity. Teachers will also participate, and learn how VR technology can be used with their students.
5. Post-intervention assessment. Following the completion of the intervention, both groups will retake the ROSE, SIA and/or knowledge questionnaires to assess the impact of the content acquisition. Comparative analysis between pre- and post-intervention data will enable evaluation of the VR game's effectiveness relative to traditional learning. Teachers will also retake their initial questionnaire, to evaluate if their perception of STEM education and technology use has differed.
6. Data analysis. Quantitative data will be analyzed using appropriate statistical methods to identify statistically significant differences within and between groups. Additionally, qualitative observations during gameplay and lectures may be collected to provide contextual insights into student engagement and behavior.

3. Expected results

This MSc work in progress is expected to produce relevant research outcomes, such as the development of an educational serious game that leverages low-cost VR technologies to support the learning of fundamental concepts in astronomy, while embedding the pillars of computational thinking (abstraction, pattern recognition, decomposition, and algorithmic thinking) into its gameplay activities. The VR-enabled serious game will designed for students in Brazilian schools, and the game will be compatible with hardware solutions, such as Meta Quest 2/3 headsets and Android devices with DIY head-mounted displays.

Another key scientific outcome is a structured, replicable research protocol combining qualitative and quantitative methods to assess the educational effectiveness of the proposed VR-enabled serious game. The protocol will utilize validated instruments like the ROSE questionnaire, a social impact assessment, and domain-specific knowledge tests to evaluate shifts in students' interest in STEM and content acquisition. The protocol will be applied in a case study with at least 30 K-12 students from two public schools in the Brazilian Northeast. A comparison between students exposed to the VR game (experimental group) and those receiving traditional instruction (control group) will help the analysis. The mixed-methods approach will combine statistical analysis with student feedback to support a comprehensive evaluation of the intervention's outcomes.

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